**Reservoirs, fluxes and residence time**

The goal of this exercise is for you to be able to accurately predict how a system can be characterized by reservoirs, processes and residence time and how a system will change when these change. To accomplish this we are going to draw analogies between a simple system of connected containers of water and the Earth’s water cycle.

The simple water system:

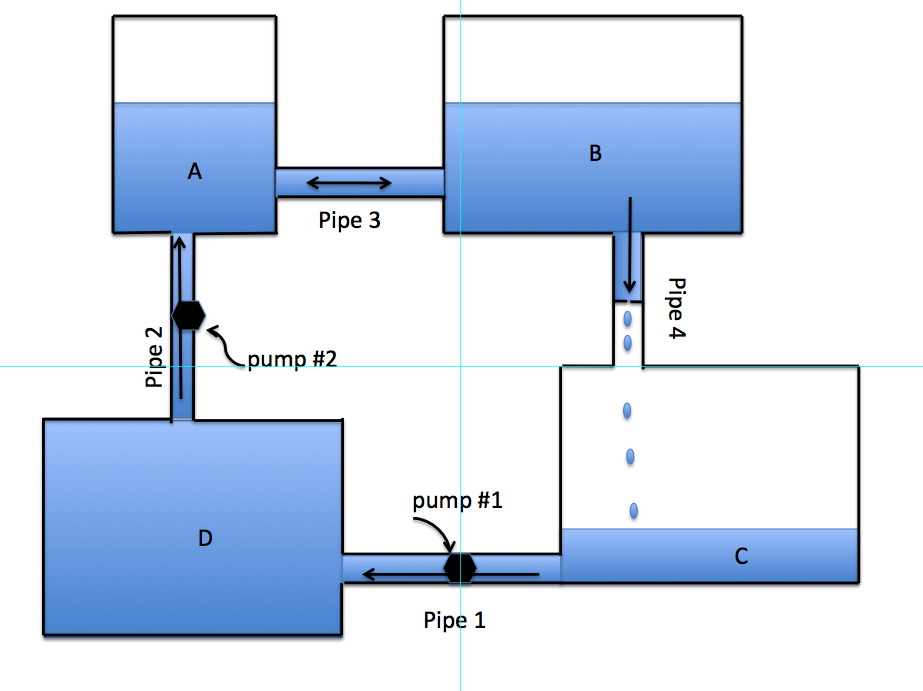


Figure 1. A simple sytem with water in 4 connected containers.

The figure above shows four containers of water with water flowing between them. The arrows show the direction of flow. The double arrow between containers A & B shows that water can flow either way through the connecting pipe. Water from container B drips into container C through a small hole in a restriction across the pipe. Water is forced from containers C and D by pumps #1 and #2. Assume that the pumps are lectric and connected to an electrc outlet by wires.

**I. Reservoirs and movement between reservoirs**

**Part 1. Alignment and inference**

There are aspects of the simple system shown above that are similar to aspects of the water cycle. For each aspect listed in table 1, list a similar aspect from the water system. Note that for each aspect of the simple system there is more than one similar aspect of the water cycle. Therefore, there is more thn one way to correctly coplete table 1. There are also relationships between aspects that are similar. In the right-hand column of figure 1, describe the relationship. Some parts of table 1 have been filled in to provide and example.

|  |  |  |
| --- | --- | --- |
| **Simple system** | **Water cycle** | **Relationship** |
| Container A | *Water vapor in atmosphere* | *Both are reservoirs* |
| Container B |  |  |
| Container C |  |  |
| Container D |  |  |
| Pipe 1 |  |  |
| Pipe 2 |  |  |
| Pipe 3 | Groundwater/stream interface | *Water moves back and forth between reservoirs* |
| Pipe 4 |  |  |
| Pump 1 | gravity | *Energy moves water from one reservoir to another* |
| Pump 2 |  |  |
| Hole in pipe 4 |  |  |

Table 1

We may use inferences about simple systems to make inferences about more complex systems. What would happen to the simple system if you made the hole in the restriction in pipe 4 larger?

Based on what you wrote in table 1, what is the analogous change that would happen in the water cycle if you made the hole in pipe 4 larger?

Figure 2 shows another simple system but with 5 containers rather than 4.

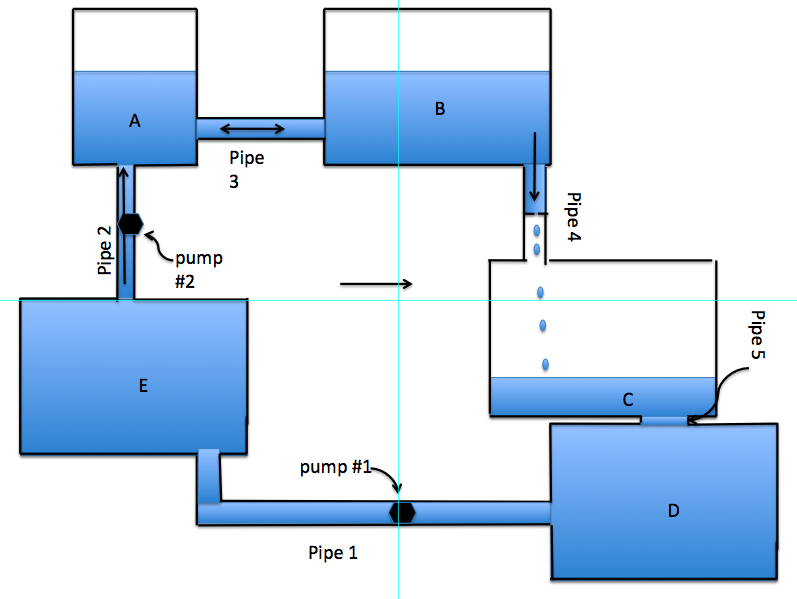


Figure 2.

Fill in table 2 as in the same way you filled in table 1 but with container A now analogous to groundwater.

|  |  |  |
| --- | --- | --- |
| **Simple system** | **Water cycle** | **Relationship** |
| Container A | *Goundwater* |  |
| Container B |  |  |
| Container C |  |  |
| Container D |  |  |
| Container E |  |  |
| Pipe 1 |  |  |
| Pipe 2 |  |  |
| Pipe 3 |  |  |
| Pipe 4 | *Air/water interface* |  |
| Hole in barrier in pipe 4 | *Evaporation* | *Energy changes water* |
| Pump 1 |  |  |

Table 2

**Part 2. Finding the Limits of an Analogy & Inference Evaluation**

While analogies are very useful, they all have their limits. In the tables 3 and 4, list those analogies and explain one limit of each with respect to what actually occurs in the water cycle. For example, if one were to have written that the hole in pipe 4 is related to the rate of evaporation of surface water into the atmosphere, then one might note the limitation that there is no energy source depicted in the simple system that would change the size of the hole.

|  |  |  |
| --- | --- | --- |
| **Simple system** | **Water cycle** | **Limitations** |
| Hole in pipe 4 |  |  |
| Pipe 1 |  |  |
| Container D |  |  |

Table 3 Fill in the water cycle column with what you wrote in table 1

|  |  |  |
| --- | --- | --- |
| **Simple system** | **Water cycle** | **Limitations** |
| Pipe 2 |  |  |
| Container C |  |  |
| Pump 2 |  |  |

Table 4 Fill in the water cycle column with what you wrote in table 2

Based on one or more of the limitations you wrote, state one aspect of the water cycle that is not analogous to what happens in the simple system.

**Part 3: Abstraction & Redescription of the domains**

When components of two domains are analogous a common principle can be used to describe both. Note that some of these common principles may have been described in table 1

For every corresponding pair of components in table 5, use a single word or phrase that can be used to describe the common relation, role or principle. If there is no correspondence, write NP in the right- hand column.

|  |  |  |
| --- | --- | --- |
| **Simple system** | **Water cycle** | **Common principle** |
| Water in containers | Water in reservoirs | *Water resides in definable states and locations* |
| Containers contain varying amounts of water | Reservoirs have a range of sizes |  |
| Containers are connected | Water moves and changes from one reservoir to another |  |
| Water flows in one or two directions between containers | Not all reservoirs are directly connected |  |
| Water both flows and is pumped between some reservoirs. | A variety of processes move and change water from one reservoir to another |  |

Table 5

**B. Residence time**

Residence time is the average amount of time that a material remains in a reservoir. In this section of the exercise, we will compare the residence time of water in the containers in the simple system with the residence time of water in the water cycle. You may recall from readings and lecture that residence times are calculated by dividing the amount of material in a reservoir by the rate of flow of matter into or out of the reservoir.

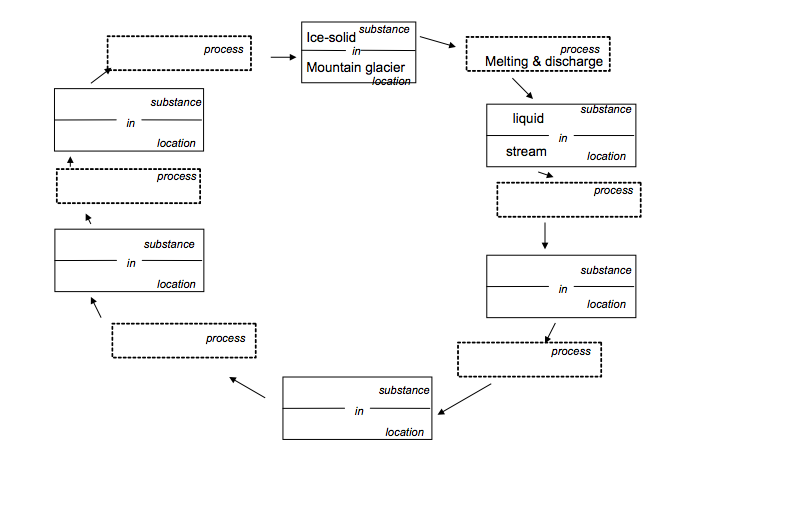
Complete table 6 by listing changes in the water cycle that are similar to changes in the simple system. In the right-hand column, write increase, decrease or no change in the residence time based on you wrote in the middle column.

|  |  |  |
| --- | --- | --- |
| **Simple system** | **Water cycle** | **Affect on residence time** |
| Remove some of the water in container A from the whole system. | *Remove some water from the oceans* | *decrease* |
| Decrease the rate of pumping (pump #1). |  | *increase* |
| Increase the hole size in pipe #4 |  |  |
| Increase the amount of water in reservoir C |  |  |

Table 6

Assessment:

1. Complete the box and arrow diagram below



2. How, if at all, global warming will change the residence time of water in the oceans? Explain your answer.